DESIGN AND CONTROL OF LARGE-SCALE GRID-CONNECTED PHOTOVOLTAIC POWER PLANT WITH FAULT RIDE-THROUGH

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SUPERVISOR'S DECLARATION

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Doctor of Philosophy.

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I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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ABSTRACT

Over the recent years, the installation of photovoltaic (PV) system and integration with electrical grid has become more widespread worldwide. With the significant and rapid increase of photovoltaic power plants (PVPPs) penetration to the electric grid, the power system operation and stability issues become crucial and this leads to continuous evaluation of grid interconnection requirements. For this purpose, the modern grid codes (GCs) require a reliable PV generation system that achieves fault ride-through (FRT) requirements. Therefore, the FRT capability becomes the state of art as one of the challenges faced by the integration of large-scale PV power stations into electrical grid that has not been fully investigated. This research proposes FRT requirements for the connection of PVPPs into Malaysian grid as new requirements. In addition, presents a comprehensive control strategy of large-scale PVPPs to enhance the FRT capability based on modern GCs connection requirements. In order to meet these requirements, there are two major issues that should be addressed. The first one is the ac over-current and dc-link over-voltage that may cause disconnection or damage to the grid inverter. The second one is the injection of reactive current to assist the voltage recovery and support the grid to overcome the voltage sag problem. To address the first issue, the dc-chopper brake controller and current limiter are used to absorb the excessive dc-voltage and limits excessive ac current, respectively, and therefore protect the inverter and ride-through the faults smoothly. After guaranteeing that the inverter is kept connected and protected, this control strategy can also ensure a very important aspect which is the reactive power support through the injection of reactive current based on the standard requirements. Feed-forward decoupling strategy based-dq control is used for smooth voltage fluctuation and reactive current injection. Furthermore, to keep the power balance between both sides of the inverter, PV array can generate a possible amount of active power according to the rating of grid inverter and voltage sag depth by operating in two modes, which are normal and FRT modes. These two modes of operation require fast and precise sag detection strategy to switch the system from normal mode to a faulty mode of operation for an efficient FRT control. For this purpose, RMS detection method has been used. In this research, the large-scale PV plant connected to the MV side of the utility grid, taking the compliance of TNB technical regulations for PVPPs into consideration has been modelled using MATLAB/Simulink with nominal rated peak power of 1500 kW. Analyses of the dynamic response for the proposed PVPP under various types of symmetrical and asymmetrical grid faults also had been investigated. As a conclusion, the PVPP connected to the power grid provided with FRT capability has been developed. The sizing of the suggested PV array is achieved in which the simulation results matched the sizing calculation results. Moreover, the results at the point of common coupling show that the proposed PVPP is compatible with TNB requirements, including the PV-grid connection method, PV inverter type, nominal voltage operating range, total harmonic distortion less than 5%, voltage unbalance less than 1%, frequency fluctuation within ± 0.1 Hz, and power factor higher than 0.9. In addition, the control simulation results presented demonstrate the effectiveness of the overall presented FRT control strategy, which aims to improve the capability of ride-through during grid faults safely, to keep the inverter connected, to ensure the safety of the system equipment, to ensure all values return to pre-fault values as soon as the fault is cleared within almost zero second as compared to the strategy without FRT control which needs around 0.25s, and to provide grid support through active and reactive power control at different types of faults based on the FRT standard requirements.

ABSTRAK

Dalam tahun-tahun kebelakangan ini, pemasangan sistem fotovoltaik (PV) dan integrasi dengan grid elektrik telah menjadi semakin meluas di seluruh dunia. Dengan peningkatan ketara dan pesat penyambungan loji janakuasa fotovoltaik (PVPPs) ke grid elektrik, isu-isu berkaitan operasi sistem kuasa dan kestabilan menjadi lebih penting dan membawa kepada penilaian berterusan terhadap syarat penyambungan ke grid. Untuk tujuan ini, baru-baru ini, kod grid moden (GCs) memerlukan sistem penjanaan PV yang boleh dipercayai dengan mencapai keperluan melangkaui ganguan (FRT). Oleh itu, keupayaan FRT menjadi sebagai salah satu cabaran yang dihadapi oleh stesen kuasa PV berskala besar bagi penyambungan ke grid elektrik yang belum disiasat sepenuhnya. Kajian ini mencadangkan keperluan FRT untuk sambungan PVPP ke grid Malaysia sebagai keperluan baru. Di samping itu, membentangkan strategi kawalan komprehensif PVPP berskala besar untuk meningkatkan keupayaan FRT berdasarkan keperluan sambungan GC moden. Untuk memenuhi keperluan penyambungan ini, terdapat dua isu utama yang perlu ditangani. Yang pertama adalah arus ulang alik (ac) terlebih arus serta arus terus (dc) terlebih voltan yang boleh menyebabkan pemotongan atau kerosakan pada penyongsang grid. Yang kedua ialah suntikan arus reaktif untuk membantu pemulihan voltan dan menyokong grid mengatasi masalah sag voltan. Untuk menangani isu pertama, pengawal brek dc-chopper dan penghad arus digunakan untuk menyerap voltan dc yang berlebihan dan mengehadkan arus ac berlebihan, membolehkan melindungi penyongsang dan melangkaui gangguan elektrik dengan lancar. Selepas menjamin bahawa penyongsang terus disambungkan dan dilindungi, strategi kawalan ini juga boleh memastikan ciri yang sangat penting iaitu memberi sokongan kuasa reaktif melalui suntikan arus reaktif mengikut keperluan standard. Tambahan pula, untuk menjaga keseimbangan kuasa antara kedua-dua belah penyongsang, PV boleh menjana jumlah kuasa aktif yang diperlukan berdasarkan kepada penarafan grid penyongsang dan kedalaman voltan sag dengan dalam operasi dua mod iaitu mod biasa dan FRT. Kedua-dua mod operasi ini memerlukan strategi pengesanan yang cepat dan tepat yang penting bagi sistem untuk beralih dari mod operasi normal ke mod operasi kawalan FRT. Untuk tujuan ini, kaedah pengesanan RMS telah digunakan. Dalam kajian ini, loji PV berskala besar yang disambungkan ke sisi MV grid utiliti, yang mengambil pematuhan peraturan teknikal TNB mengenai penyambungan PVPP telah dimodelkan menggunakan MATLAB/Simulink dengan nominal kuasa puncak tertinggi 1500 kW. Analisa tindak balas dinamik untuk PVPP yang dicadangkan di bawah pelbagai jenis gangguan grid simetri dan bukan simetri juga telah dijalankan. Sebagai kesimpulan, reka bentuk lengkap PVPP yang disambungkan kepada grid kuasa yang disediakan dengan keupayaan FRT telah dilbangunkan. Rekabentuk saiz PV yang dicadangkan berdasarkan pengiraan ukuran telah dicapai. Selain itu, keputusan di titik gandingan bersama menunjukkan bahawa PVPP yang dicadangkan adalah bersesuaian dengan syarat keperluan TNB termasuk kaedah sambungan PV-grid, jenis penyongsang PV, rangkaian operasi voltan nominal, jumlah harmonik gangguan kurang daripada 5%, ketidakimbangan voltan kurang dari 1% , julat frekuensi dalam ± 0.1 Hz, dan factor kuasa lebih tinggi daripada 0.9. Di samping itu, hasil simulasi kawalan yang dibentangkan menunjukkan keberkesanan strategi kawalan yang dicadangkan secara keseluruhan, meningkatkan keupayaan melangkaui gangguan elektrik grid dengan selamat, memastikan penyongsang sentiasa terhubung, memastikan keselamatan peralatan sistem, semua nilai kembali kepada nilai pra-gangguan sebaik sahaja gangguan dibersihkan dalam masa hampir sifar saat berbanding tanpa kawalan yang memerlukan sekitar 0.25s, dan juga memberi sokongan kepada grid melalui kawalan kuasa aktif dan reaktif pada pelbagai jenis gangguan elektrik berdasarkan syarat keperluan FRT.

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C_{dc}	DC-link capacitor
CO_2	Carbon dioxide
d/q	Components of that variable in SRF
f	Grid frequency
f_c	Switching frequency
$f_{carrier}$	Carries frequency
G	Sun irradiation
i_{abc}	Grid currents
i_{ia} i_{ib} i_{ic}	Inverter three-phase current
I_D	Diode current of the PV cell
I_d	Active current injected to the grid
I_d^*	Active current reference
i_{dref}	Active current reference of the inverter
$\tilde{i}_{dref}$	Output active current reference of the current limiter
I_{max}	Maximum current of the photovoltaic array
I_{mpp}	Current of the PV module/array at the maximum power point
I_n	Normal value of the inverter-rated current
I_P	Shunt current of the solar module
I_{Ph}	Photo current of the solar module
I_q	Reactive current injected to the grid
I_q^*	Reactive current reference
I_{qr}	Ratio of injected reactive current to the nominal current
I_{sat}	Reverse saturation current of the solar module
I_{sc}	Short circuit current
I_{THD}	Current total harmonic distortion
k_p, k_i	PI parameter of current loop
k_p, k_i	PI parameter of the voltage loop
L	Filter of the inverter
m	Modulation index
N_{cell}	Numbers of cells per module
N_{pv}	Total numbers of PV array modules (generators)

N_{pvs}	Number of PV modules in series
N_{pvst}	Number of the parallel strings
P	Instantaneous active power
P_{inj}	Active power injected to the grid
P_{max}	The maximum available output power
P_{mpp}	Power of the PV array at the maximum power point
P_{pv}	Generated power by the PV array
Q	Instantaneous reactive power
Q_{inj}	Injected reactive power to the grid
R	Filter of the inverter
R_{ch}	Chopper resistance
R_P	Equivalent parallel resistance of the solar module
R_S	Equivalent series resistance of the solar module
T	The Temperature
t	Time in second
V^+	Positive sequence of the voltage
V^-	Negative sequence of the voltage
V_{abc}	Grid voltage
V_d	Active voltage in SRF
V_d^*	Active voltage reference in SRF
V_{dc}	Dc-link voltage
V_{gn}	Nominal grid voltage
V_{ia} V_{ib} V_{ic}	inverter voltage
V_{max}	Maximum voltage of the photovoltaic array
V_{mpp}	Voltage of the PV module/array at the maximum power point
V_{oc}	Open circuit voltage
V_{pg}	Present grid voltage before faults
V_q	Reactive voltage in synchronous reference frame.
V_q^*	Reactive voltage reference
V_T	The thermal voltage
V_{THD}	Voltage total harmonic distortion
ω	Angular frequency
ΔP	Change in the power of MPPT

α/β	Components of that variable in stationary frame
θ_{PLL}	Phase angle of the PLL
α_v	Temperature coefficients of open circuit voltage
α_i	Temperature coefficients of short circuit current

LIST OF ABBREVIATIONS

3-ph	Three phase
ac	Alternating current
AEMC	Australian Energy Market Commission
ANN	Artificial neural network
DCL	Adaptive dc-link
BDEW	German Association of Energy and Water Industries
CC	Constant current
CSI	Current Source Inverters
CV	Constant voltage
DB	Dead beat
dc	Direct current
DG	distribution generator
DPGS	Distributed power generation systems
DSO	Distribution system operators
DVR	Dynamic voltage restorer
DVS	Dynamic voltage support
ECM	Energy Commission Malaysia
FACTS	Flexible ac transmission system
FDP	Fuel diversification policy
FF	Fill factor
FFT	Fast Fourier transform
FiT	Feed-in-Traffic
FL	Fuzzy logic
FLC	Fuzzy logic control
FLS	Feedback linearization strategy
FL-GA	Fuzzy logic-genetic algorithm
FRT	Fault ride through
GA	Genetic algorithm
GB/T	Guobiao Standards/ recommended (Chinese national standards)
GC	Grid code
GCPPPs	Grid-connected photovoltaic power plants

GCPVS	Grid-connected photovoltaic system
GTO	Gate turn-off thyristor
GW	Giga watt
HC	Hill climbing
IEA	International Energy Agency
IEC	International Electro-technical Commission
IEEE	Institute of Electrical and Electronics Engineers
IGBT	Insulated-gate bipolar transistor
INC	Incremental conductance
IPP	Independent Power Producers
LL	Line to line
LLG	Line to line to ground
LV	Low voltage
LVRT	Low voltage ride-through
MDS	Main distribution substation
MOSFET	Metal oxide semiconductor field effect transistor
MPP	Maximum power point
MPPT	Maximum power point tracking
MV	Medium voltage
MVA	Mega volt-ampere
MW	Megawatt
P&O	Perturb and observe
p.u	Per unit
PCC	Point of common coupling
PI	Proportional integral
PID	Proportional integral derivative
PF	Power factor
PLL	Phase locked loop
PPU	Pencawang pembahagian utama-main distribution substation
PR	Proportional resonant
PSO	Power system operator
PV	Photovoltaic
PVPP	Photovoltaic power plants

PWM	Pulse width modulation
RC	Repetitive current
RE	Renewable energy
RM	Malaysian ringgit
RMS	Root mean square
SAPVS	Stand-alone photovoltaic system
SCESS	Supercapacitor energy storage system
SDBR	Series dynamic breaking resistor
SEDA	Sustainable energy development authority
SGCT	Symmetrical gate commutated thyristor
SLG	Single line to ground
sq km	Square kilometre
SRF-PLL	Synchronous reference frame phase-locked loop
STATCOM	Static compensator
STC	Standard test conditions
SVC	Static VAR compensator
THD	Total harmonic distortion
TNB	Tenaga Nasional Berhad
USANAERC	United States-north American electric Reliability Corporation
USAPREPA	United States-Puerto Rico Electric Power Authority
VAR	Volt-ampere reactive
VCO	Voltage controlled oscillator
VSI	Voltage source inverters
VUF	Voltage imbalance factor
WPP	Wind power plant
ZVRT	Zero voltage ride through

REFERENCES

Abdul Kadir, A. F., Khatib, T., & Elmenreich, W. (2014). Integrating photovoltaic systems in power system: power quality impacts and optimal planning challenges. *International Journal of Photoenergy, 2014*.

Abu-Jasser, A. (2010). A stand-alone photovoltaic system, case study: a residence in Gaza. *Journal of Applied Sciences in Environmental Sanitation, 5*(1), 81-91.

AEMC. (2015). Template for Generator Compliance Programs Review 2015. Retrieved 20-June, 2017, from http://www.aemc.gov.au/Markets-Reviews-Advice

Afshari, E., Farhangi, B., Yang, Y., & Farhangi, S. (2017). *A low-voltage ride-through control strategy for three-phase grid-connected PV systems.* Paper presented at the Power and Energy Conference at Illinois (PECI), 2017 IEEE.

Ahmad, S., Ab Kadir, M. Z. A., & Shafie, S. (2011). Current perspective of the renewable energy development in Malaysia. *Renewable and Sustainable Energy Reviews, 15*(2), 897-904.

Akorede, M. F. (2012). *Enhancing the solar energy potential in malaysia using the concentrated photovoltaic (CPV) technology.* Paper presented at the Planet under Pressure 2012 Conferences.

Australian Energy Market Commission (AEMC). (2016). National Electricity Rules Version 80. Retrieved 12-Jun, 2017, from http://www.aemc.gov.au/Energy-Rules/National-electricity-rules/Rules/National-Electricity-Rules-Version-80

Ayub, M., Gan, C. K., & Kadir, A. F. A. (2014). *The impact of grid-connected PV systems on Harmonic Distortion.* Paper presented at the Innovative Smart Grid Technologies-Asia (ISGT Asia), 2014 IEEE.

Azevedo, G. M., Vazquez, G., Luna, A., Aguilar, D., & Rolan, A. (2009). *Photovoltaic inverters with fault ride-through capability.* Paper presented at the 2009 IEEE International Symposium on Industrial Electronics.

Azit, A., Sulaiman, S., Hussein, Z., Balakhrisnan, M., Busrah, A., Devaraju, P., . . . Ismail, M. (2012). TNB technical guidebook on grid-interconnection of photovoltaic power generation system to LV and MV networks (pp. 1-38): Tenaga Nasional Berhad, Malaysia.

Badrzadeh, B., & Halley, A. (2015). Challenges associated with assessment and testing of fault ride-through compliance of variable power generation in Australian national electricity market. *IEEE Transactions on Sustainable Energy, 6*(3), 1160-1168.

Bae, Y., Vu, T.-K., & Kim, R.-Y. (2013). Implemental control strategy for grid stabilization of grid-connected PV system based on German grid code in symmetrical low-to-medium voltage network. *IEEE Transactions on Energy Conversion, 28*(3), 619-631.

Banu, I. V., & Istrate, M. (2014). *Study on three-phase photovoltaic systems under grid faults.* Paper presented at the Electrical and Power Engineering (EPE), 2014 International Conference and Exposition on.

Barge, S. A., & Jagtap, S. (2013). Harmonic Analysis of Sinusoidal Pulse Width Modulation. *International Journal of Advanced Electrical and Electronics Engineering, 2*(5), 13-16.

Basso, T., Hambrick, J., & DeBlasio, D. (2012). Update and review of IEEE P2030 Smart Grid Interoperability and IEEE 1547 interconnection standards *2012 IEEE PES Innovative Smart Grid Technologies (ISGT)*.

Basso, T. S., & DeBlasio, R. (2004). IEEE 1547 series of standards: interconnection issues. *IEEE Transactions on power electronics*, *19*(5), 1159-1162. doi: 10.1109/TPEL.2004.834000

Bellia, H., Youcef, R., & Fatima, M. (2014). A detailed modeling of photovoltaic module using MATLAB. *NRIAG Journal of Astronomy and Geophysics, 3*(1), 53-61.

Benz, C. H., Franke, W.-T., & Fuchs, F. W. (2010). *Low voltage ride through capability of a 5 kW grid-tied solar inverter.* Paper presented at the Power Electronics and Motion Control Conference (EPE/PEMC), 2010 14th International.

Bică, D., Dulău, M., Muji, M., & Dulău, L. I. (2016). Photovoltaic Power Plant Grid Integration in the Romanian System–Technical Approaches *Renewable Energy-Utilisation and System Integration*: InTech.

Blaabjerg, F., Teodorescu, R., Liserre, M., & Timbus, A. V. (2006). Overview of control and grid synchronization for distributed power generation systems. *IEEE Transactions on Industrial Electronics, 53*(5), 1398-1409.

Blooming, T. M., & Carnovale, D. J. (2006). *Application of IEEE Std 519-1992 harmonic limits.* Paper presented at the Pulp and Paper Industry Technical Conference, 2006. Conference Record of Annual.

Bonaldo, J. P., Schiavon, G., Paredes, H. K. M., & Pomilio, J. A. (2017). *Multifunctional operation of current controlled VSI based on the harmonic content of PCC voltage.* Paper presented at the Power Electronics for Distributed Generation Systems (PEDG), 2017 IEEE 8th International Symposium on.

Bouraiou, A., Hamouda, M., Chaker, A., Sadok, M., Mostefaoui, M., & Lachtar, S. (2015). Modeling and simulation of photovoltaic module and array based on one and two diode model using Matlab/Simulink. *Energy Procedia, 74*, 864-877.

Bundesverband der Energieund Wasserwirtschaft (BDEW). (2008). Technische Richtlinie Erzeugungsanlagen am Mittelspannungsnetz – Richtlinie für Anschluss und Parallelbetrieb von Erzeugungsanlagen am Mittelspannungsnetz. Retrieved June, 2017, from https://www.bdew.de/

Cabrera-Tobar, A., Bullich-Massagué, E., Aragüés-Peñalba, M., & Gomis-Bellmunt, O. (2016). Review of advanced grid requirements for the integration of large scale photovoltaic power plants in the transmission system. *Renewable and Sustainable Energy Reviews, 62*, 971-987.

Carrasco, J. E.-G., Tena, J., Ugena, D., Alonso-Martinez, J., Santos-Martin, D., & Arnaltes, S. (2013). Testing low voltage ride through capabilities of solar inverters. *ELECTR POW SYST RES, 96*, 111-118. doi: doi.org/10.1016/j.epsr.2012.10.011

Castilla, M., Miret, J., Camacho, A., Matas, J., & de Vicuña, L. G. (2014). Voltage support control strategies for static synchronous compensators under unbalanced voltage sags. *IEEE Transactions on Industrial Electronics, 61*(2), 808-820.

CEI-Comitato Elettrotecnico Italiano. (2014). Reference technical rules for the connection of active and passive consumers to the HV and MV electrical networks of distribution Company. Retrieved 23-Aug., 2016, from http://www.ceiweb.it/

Center, F. S. E. (2001). Grid-connected photovoltaic system design review and approval: FSEC-CP.

Cha, H., Vu, T.-K., & Kim, J.-E. (2009). *Design and control of Proportional-Resonant controller based Photovoltaic power conditioning system.* Paper presented at the Energy Conversion Congress and Exposition, 2009. ECCE 2009. IEEE.

Charles, J.-P., Hannane, F., El-Mossaoui, H., Zegaoui, A., Nguyen, T., Petit, P., & Aillerie, M. (2014). Faulty PV panel identification using the Design of Experiments (DoE) method. *International Journal of Electrical Power & Energy Systems, 57*, 31-38.

Chen, P.-C., Chen, P.-Y., Liu, Y.-H., Chen, J.-H., & Luo, Y.-F. (2015). A comparative study on maximum power point tracking techniques for photovoltaic generation systems operating under fast changing environments. *Solar Energy, 119*, 261-276.

Chen, S., Lai, Y., Tan, S.-C., & Tse, C. K. (2008). Analysis and design of repetitive controller for harmonic elimination in PWM voltage source inverter systems. *IET Power Electronics, 1*(4), 497-506.

Chen, T.-H., Yang, C.-H., & Yang, N.-C. (2013). Examination of the definitions of voltage unbalance. *International Journal of Electrical Power & Energy Systems, 49*, 380-385.

Chine, W., Mellit, A., Pavan, A. M., & Kalogirou, S. (2014). Fault detection method for grid-connected photovoltaic plants. *Renewable Energy, 66*, 99-110.

Chua, S. C., & Oh, T. H. (2012). Solar energy outlook in Malaysia. *RENEW SUST ENERG REV, 16*(1), 564-574. doi: doi.org/10.1016/j.rser.2011.08.022

Chuah, D. G., & Lee, S. (1981). Solar radiation estimates in Malaysia. *Solar Energy, 26*(1), 33-40.

Cleveland, F. (2008). *IEC 61850-7-420 communications standard for distributed energy resources (DER).* Paper presented at the Power and Energy Society General Meeting-Conversion and Delivery of Electrical Energy in the 21st Century, 2008 IEEE.

Crăciun, B.-I., Kerekes, T., Séra, D., & Teodorescu, R. (2012). *Overview of recent grid codes for PV power integration.* Paper presented at the Optimization of Electrical and Electronic Equipment (OPTIM), 2012 13th International Conference on.

de Carvalho, R., Nielson, R., Lima, C., Kopcak, I., Vieira, F., & de Araújo, S. (2013). *Operational conditions analyses of distributed generation (DG) connected on power distribution grid based on ieee Std. 1547.* Paper presented at the Innovative Smart Grid Technologies Latin America (ISGT LA), 2013 IEEE PES Conference On.

de Souza, V. R. F. B., Alves Filho, M., & de Oliveira, K. C. (2016). *Analysis of power quality for photovoltaic systems connected to the grid.* Paper presented at the Harmonics and Quality of Power (ICHQP), 2016 17th International Conference on.

Desai, H. P., & Patel, H. (2007). *Maximum power point algorithm in PV generation: An overview*. Paper presented at the 2007 7th International Conference on Power Electronics and Drive Systems.

Diaz-Franco, F., Vu, T., El Mezyani, T., & Edrington, C. S. (2016). *Low-voltage ride-through for PV systems using model predictive control approach.* Paper presented at the North American Power Symposium (NAPS), 2016.

Ding, G., Gao, F., Tian, H., Ma, C., Chen, M., He, G., & Liu, Y. (2016). Adaptive DC-link voltage control of two-stage photovoltaic inverter during low voltage ride-through operation. *IEEE Transactions on power electronics, 31*(6), 4182-4194.

Economic Plan Unit. (2015). 9th,10th and 11th Malysian plane. Retrieved 25, Jan, 2016, from http://www.epu.gov.my/en/home

Elrayah, M. O. M. (2017). *Performance Analysis of Grid Connected Photovoltaic System.* Sudan University of Science and Technology.

Energinet, D. (2015). Technical regulation 3.2. 2 for PV power plants with a power output above 11 kW. *Tech. Rep.*

Energy Commission Malaysia. (2010). The Malaysian grid and distribution codes. Retrieved 11-Aug., 2016, from http://www.tnb.com.my/business/malaysian-grid-code.html

Energy Commission Malaysia (ECM). (2017). Grid Code for Peninsular Malaysia. Retrieved 16-June, 2017, from http://st.gov.my

Etxegarai, A., Eguia, P., Torres, E., Buigues, G., & Iturregi, A. (2017). Current procedures and practices on grid code compliance verification of renewable power generation. *Renewable and Sustainable Energy Reviews*.

Farhoodnea, M., Mohamed, A., Shareef, H., & Zayandehroodi, H. (2013). Power quality analysis of grid-connected photovoltaic systems in distribution networks. *Przeglad Elektrotechniczny (Electrical Review), 2013*, 208-213.

Figueira, H. H., Hey, H. L., Schuch, L., Rech, C., & Michels, L. (2015). *Brazilian grid-connected photovoltaic inverters standards: A comparison with IEC and IEEE.* Paper presented at the Industrial Electronics (ISIE), 2015 IEEE 24th International Symposium on.

Foley, A., & Olabi, A. G. (2017). Renewable energy technology developments, trends and policy implications that can underpin the drive for global climate change. *Renewable and Sustainable Energy Reviews, 68*, 1112-1114. doi: http://dx.doi.org/10.1016/j.rser. 2016.12.065

Foster, S., Xu, L., & Fox, B. (2006). *Grid integration of wind farms using SVC and STATCOM.* Paper presented at the Universities Power Engineering Conference, 2006. UPEC'06. Proceedings of the 41st International.

Fuchs, E., & Masoum, M. A. (2011). *Power quality in power systems and electrical machines*: Academic press, Boston.

García-Sánchez, T., Gómez-Lázaro, E., & Molina-García, A. (2014). *A Review and Discussion of the Grid-Code Requirements for Renewable Energy Sources in Spain.* Paper presented at the International Conference on Renewable Energies and Power Quality (ICREPQ'14), Cordoba, Spain April.

GB/T. (2012). Technical Rule for PV Power Station Connected to Power Grid. *Chinese Enterprise Standards*.

Gevorgian, V., & Booth, S. (2013). Review of PREPA technical requirements for interconnecting wind and solar generation. *National Renewable Energy Laboratory: Golden, CO, USA.*

Ghaib, K., & Ben-Fares, F.-Z. (2017). A design methodology of stand-alone photovoltaic power systems for rural electrification. *Energy conversion and management, 148*, 1127-1141.

Gkavanoudis, S. I., & Demoulias, C. S. (2014). A combined fault ride-through and power smoothing control method for full-converter wind turbines employing Supercapacitor Energy Storage System. *Electric Power Systems Research, 106*, 62-72.

Global Status Report. (2017). Renewables 2016 Global Status Report-REN21. Retrieved 22 February, 2017, from http://www.ren21.net/wp-content/uploads/2016/06/GSR_2016_ Full_Report.pdf

Gonen, T. (2016). *Electric power distribution engineering*: CRC press.

Grainger, J. J., & Stevenson, W. D. (1994). *Power system analysis*: McGraw-Hill.

Guo, X.-Q., Wu, W.-Y., & Gu, H.-R. (2011). Phase locked loop and synchronization methods for grid-interfaced converters: a review. *Przeglad Elektrotechniczny, 87*(4), 182-187.

Hasanien, H. M. (2016). An Adaptive Control Strategy for Low Voltage Ride Through Capability Enhancement of Grid-Connected Photovoltaic Power Plants. *IEEE Transactions on Power Systems, 31*(4), 3230-3237.

Hassaine, L. (2016). Power Converters and Control of Grid-Connected Photovoltaic Systems *Renewable Energy in the Service of Mankind Vol II* (pp. 497-504): Springer.

Hassaine, L., OLias, E., Quintero, J., & Salas, V. (2014). Overview of power inverter topologies and control structures for grid connected photovoltaic systems. *Renewable and Sustainable Energy Reviews, 30,* 796-807.

Hojabri, M., & Soheilirad, M. (2014). *Harmonic Distortion in an Off-Grid Renewable Energy System with Different Loads.* Paper presented at the Proceedings of the International MultiConference of Engineers and Computer Scientists.

Honrubia-Escribano, A., Ramirez, F. J., Gómez-Lázaro, E., Garcia-Villaverde, P. M., Ruiz-Ortega, M. J., & Parra-Requena, G. (2018). Influence of solar technology in the economic performance of PV power plants in Europe. A comprehensive analysis. *Renewable and Sustainable Energy Reviews, 82*, 488-501.

Hossain, J., & Mahmud, A. (2014). *Renewable energy integration: challenges and solutions*: Springer Science & Business Media.

Hossain, M. K., & Ali, M. H. (2014). *Low voltage ride through capability enhancement of grid connected PV system by SDBR.* Paper presented at the T&D Conference and Exposition, 2014 IEEE PES.

Huang, T., Shi, X., Sun, Y., & Wang, D. (2014). *Three-phase photovoltaic grid-connected inverter based on feedforward decoupling control.* Paper presented at the Materials for Renewable Energy and Environment (ICMREE), 2013 International Conference on.

IEEE power and energy society. (2009). Electrical Power System Competition EPSCOM 2009,Project Based Learning (PBL). *1*, 1-34.

IEEE Std. 929-2000. (2000). IEEE Recommended Practice for Utility Interface of Photovoltaic (PV) Systems. *IEEE Std 929-2000*, i. doi: 10.1109/IEEESTD.2000.91304

International Energy Agency (IEA). (2017). 2016 snapshot of global photovoltaic markets. Retrieved 22-June, 2017, from http://www.iea-pvps.org/index.php?id=267

Ishaque, K., Salam, Z., & Lauss, G. (2014). The performance of perturb and observe and incremental conductance maximum power point tracking method under dynamic weather conditions. *Applied Energy, 119*, 228-236.

Islam, G. M. S., Al-Durra, A., Muyeen, S. M., & Tamura, J. (2011, 7-10 Nov. 2011). *Low voltage ride through capability enhancement of grid connected large scale photovoltaic system.* Paper presented at the IECON 2011 - 37th Annual Conference of the IEEE Industrial Electronics Society.

Islam, M. R., Guo, Y., & Zhu, J. (2014). Power Converters for Small-to Large-Scale Photovoltaic Power Plants *Power Converters for Medium Voltage Networks* (pp. 17-49): Springer.

Jafar, A. H., Al-Amin, A. Q., & Siwar, C. (2008). Environmental impact of alternative fuel mix in electricity generation in Malaysia. *Renewable Energy, 33*(10), 2229-2235.

Jain, S., & Agarwal, V. (2007). New current control based MPPT technique for single stage grid connected PV systems. *Energy conversion and management, 48*(2), 625-644.

Jana, J., Saha, H., & Bhattacharya, K. D. (2016). A review of inverter topologies for single-phase grid-connected photovoltaic systems. *Renewable and Sustainable Energy Reviews*.

Jayakrishnan, R., & Sruthy, V. (2015). *Fault ride through augmentation of microgrid.* Paper presented at the Advancements in Power and Energy (TAP Energy), 2015 International Conference on.

Jenkins, N., & Thornycroft, J. (2017). Grid Connection of Photovoltaic Systems: Technical and Regulatory Issues *McEvoy's Handbook of Photovoltaics (Third Edition)* (pp. 847-876): Elsevier.

Johari, A., Hafshar, S. S., Ramli, M., & Hashim, H. (2011). *Potential use of solar photovoltaic in Peninsular Malaysia.* Paper presented at the Clean Energy and Technology (CET), 2011 IEEE First Conference on, Kuala Lumpur, Malaysia.

Kale, M., & Ozdemir, E. (2005). An adaptive hysteresis band current controller for shunt active power filter. *Electric Power Systems Research, 73*(2), 113-119.

Kamarzaman, N. A., & Tan, C. W. (2014). A comprehensive review of maximum power point tracking algorithms for photovoltaic systems. *Renewable and Sustainable Energy Reviews, 37*, 585-598.

Kanjiya, P., Singh, B., Chandra, A., & Al-Haddad, K. (2013). "SRF Theory Revisited" to Control Self-Supported Dynamic Voltage Restorer (DVR) for Unbalanced and Nonlinear Loads. *IEEE Transactions on Industry Applications, 49*(5), 2330-2340.

Khan, M. J., & Mathew, L. (2017). Different kinds of maximum power point tracking control method for photovoltaic systems: a review. *Archives of Computational Methods in Engineering, 24*(4), 855-867.

Kim, S.-T., Kang, B.-K., Bae, S.-H., & Park, J.-W. (2013). Application of SMES and grid code compliance to wind/photovoltaic generation system. *IEEE Transactions on Applied Superconductivity, 23*(3), 5000804-5000804.

Klapp, D., & Vollkommer, H. T. (2014). *Application of an intelligent static switch to the point of common coupling to satisfy IEEE 1547 compliance.* Paper presented at the Power Engineering Society General Meeting, 2007. IEEE, Tampa, FL, USA.

Kobayashi, H. (2012). *Fault ride through requirements and measures of distributed PV systems in Japan.* Paper presented at the 2012 IEEE Power and Energy Society General Meeting.

Kothari, D. P., & Nagrath, I. (2003). *Modern power system analysis*: Tata McGraw-Hill Education.

Kumar, L. A., & Surekha, P. (2015). Solar PV and Wind Energy Conversion Systems.

Kurokawa, K., Komoto, K., van der Vleuten, P., & Faiman, D. (2007). Energy from the desert: Practical proposals for Very Large Scale Photovoltaic Systems: Earthscan: London.

Lammert, G., Boemer, J. C., Premm, D., Glitza, O., Ospina, L. D. P., Fetzer, D., & Braun, M. (2017). *Impact of fault ride-through and dynamic reactive power support of photovoltaic systems on short-term voltage stability.* Paper presented at the PowerTech, 2017 IEEE Manchester.

Latran, M. B., & Teke, A. (2015). A novel wavelet transform based voltage sag/swell detection algorithm. *International Journal of Electrical Power & Energy Systems, 71*, 131-139.

Lauria, D., & Coppola, M. (2014). Design and control of an advanced PV inverter. *Solar Energy, 110*, 533-542.

Lee, J.-S., & Lee, K. B. (2013). Variable dc-link voltage algorithm with a wide range of maximum power point tracking for a two-string PV system. *Energies, 6*(1), 58-78.

Li, K., Qian, J., Wu, H., Li, T., & Yang, J. (2015). *Research on Low Voltage Ride through of the Grid-Connected PV System.* Paper presented at the International Conference on Advances in Energy, Environment and Chemical Engineering (AEECE-2015).

Li, Y., Li, R., Liu, H., Cai, H., & Dong, J. China's Distributed Generation of Electric Power-Current Situation And Prospect.

Liu, Y.-J., Lan, P.-H., Lin, H.-H., Chiu, T.-Y., & Chen, H.-W. (2013). *Power conditioner interconnection test system of distributed resources based on IEEE 1547 standard.* Paper presented at the Future Energy Electronics Conference (IFEEC), 2013 1st International.

Lu, C., Zhou, Z., Jiang, A., Luo, M., Shen, P., & Han, Y. (2016). *Comparative performance evaluation of phase-locked loop (PLL) algorithms for single-phase grid-connected converters.* Paper presented at the Power Electronics and Motion Control Conference (IPEMC-ECCE Asia), 2016 IEEE 8th International.

Lu, S.-y., Wang, L., Ke, S.-c., Chang, C.-h., & Yang, Z.-h. (2014). *Analysis of measured power-quality results of a PV system connected to Peng-Hu Power System.* Paper presented at the Industry Applications Society Annual Meeting, 2014 IEEE.

Magoro, B., & Khoza, T. (2012). Grid connection code for renewable power plants connected to the electricity transmission system or the distribution system in South Africa. *no. November*.

Mahela, O. P., & Shaik, A. G. (2017). Comprehensive overview of grid interfaced solar photovoltaic systems. *Renewable and Sustainable Energy Reviews, 68*, 316-332.

Mahmoud, M. M., & Ibrik, I. H. (2006). Techno-economic feasibility of energy supply of remote villages in Palestine by PV-systems, diesel generators and electric grid. *RENEW SUST ENERG REV, 10*(2), 128-138. doi: doi.org/10.1016/j.rser.2004.09.001

Manikanta, B., Kesavarao, G., & Talati, S. (2017). LVRT of Grid Connected PV System with Energy Storage. *International Science Press, 10*(5), 75-86.

Mekhilef, S., Safari, A., Mustaffa, W., Saidur, R., Omar, R., & Younis, M. (2012). Solar energy in Malaysia: current state and prospects. *Renewable and Sustainable Energy Reviews, 16*(1), 386-396.

Merabet, A., & Labib, L. (2017). *Control system for dual-mode operation of grid-tied photovoltaic and wind energy conversion systems with active and reactive power injection.*, saint mary's university, Halifax, Nova Scotia, Canada.

Merabet, A., Labib, L., & Ghias, A. M. (2017). Robust Model Predictive Control for Photovoltaic Inverter System with Grid Fault Ride-Through Capability. *IEEE Transactions on Smart Grid*.

Milanovic, J. V., & Zhang, Y. (2010). Modeling of FACTS devices for voltage sag mitigation studies in large power systems. *IEEE transactions on power delivery, 25*(4), 3044-3052.

Mohammad, N., Quamruzzaman, M., Hossain, M. R. T., & Alam, M. R. (2013). Parasitic effects on the performance of DC-DC SEPIC in photovoltaic maximum power point tracking applications. *Smart Grid and Renewable Energy, 4*(01), 113.

Mohseni, M., & Islam, S. M. (2012). Review of international grid codes for wind power integration: Diversity, technology and a case for global standard. *Renewable and Sustainable Energy Reviews, 16*(6), 3876-3890.

Neumann, T., & Erlich, I. (2012). *Modelling and control of photovoltaic inverter systems with respect to German grid code requirements.* Paper presented at the 2012 IEEE Power and Energy Society General Meeting.

Nugroho, A. (2010). The impact of solar chimney geometry for stack ventilation in Malaysia's single storey terraced house. *Malaysia's Geography*, 163-177.

Obi, M., & Bass, R. (2016). Trends and challenges of grid-connected photovoltaic systems–A review. *Renewable and Sustainable Energy Reviews*, *58*, 1082-1094.

Omar, A. M., & Zainuddin, H. (2014). Modeling and Simulation of Grid Inverter in Grid-Connected Photovoltaic System. *International Journal of Renewable Energy Research (IJRER), 4*(4), 949-957.

Ong, H., Mahlia, T., & Masjuki, H. (2011). A review on energy scenario and sustainable energy in Malaysia. *Renewable and Sustainable Energy Reviews, 15*(1), 639-647.

Orłowska-Kowalska, T., Blaabjerg, F., & Rodríguez, J. (2014). *Advanced and intelligent control in power electronics and drives,T. Orłowska-Kowalska (Ed.).* (Vol. 531): Springer.

Pannell, G., Zahawi, B., Atkinson, D. J., & Missailidis, P. (2013). Evaluation of the performance of a DC-link brake chopper as a DFIG low-voltage fault-ride-through device. *IEEE Transactions on Energy Conversion, 28*(3), 535-542.

Parvez, M., Elias, M., Rahim, N., & Osman, N. (2016). Current control techniques for three-phase grid interconnection of renewable power generation systems: A review. *Solar Energy, 135*, 29-42.

Patel, D., Goswami, A. K., & Singh, S. K. (2015). Voltage sag mitigation in an Indian distribution system using dynamic voltage restorer. *International Journal of Electrical Power & Energy Systems, 71*, 231-241.

Perpinias, I., Papanikolaou, N., & Tatakis, E. (2015). Fault ride through concept in low voltage distributed photovoltaic generators for various dispersion and penetration scenarios. *Sustainable Energy Technologies and Assessments, 12*, 15-25.

Petrović, I., Šimić, Z., & Vražić, M. (2014). Advanced PV Plant Planning based on Measured Energy Production Results-Approach and Measured Data Processing. *Advances in Electrical and Computer Engineering, 14*(1), 49-54.

Pigazo, A., Liserre, M., Mastromauro, R. A., Moreno, V. M., & Dell'Aquila, A. (2009). Wavelet-based islanding detection in grid-connected PV systems. *IEEE Transactions on Industrial Electronics, 56*(11), 4445-4455.

Preda, T. N., Uhlen, K., & Nordg, D. E. (2012, 29-30 May 2012). *An overview of the present grid codes for integration of distributed generation.* Paper presented at the Integration of Renewables into the Distribution Grid, CIRED 2012 Workshop.

Ram, J. P., Babu, T. S., & Rajasekar, N. (2017). A comprehensive review on solar PV maximum power point tracking techniques. *Renewable and Sustainable Energy Reviews, 67*, 826-847.

Red Electrica. (2008). Technical requirements for wind power and photovoltaic installationsand any generating facilities whose technology does not consist on asynchronous generator directly connected to the grid, issued by RedElectrica, October 2008, O.P. 12.2 Restricted to the technicalrequirements of wind power and photovoltaic facilities (draft). Retrieved 23-Aug

2016, from (translated in English by: www.aeolica.es)

Reddy, K. R., Babu, N. R., & Sanjeevikumar, P. (2018). A Review on Grid Codes and Reactive Power Management in Power Grids with WECS *Advances in Smart Grid and Renewable Energy* (pp. 525-539): Springer.

Ruiz, A. (2011). System aspects of large scale implementation of a photovoltaic power plant.

Saad, N. H., El-Sattar, A. A., & Mansour, A. E.-A. M. (2016). Improved particle swarm optimization for photovoltaic system connected to the grid with low voltage ride through capability. *Renewable Energy, 85*, 181-194.

Sannino, A., Miller, M. G., & Bollen, M. H. (2000). *Overview of voltage sag mitigation.* Paper presented at the Power Engineering Society Winter Meeting, 2000. IEEE.

Saravanan, S., & Babu, N. R. (2016). Maximum power point tracking algorithms for photovoltaic system–A review. *Renewable and Sustainable Energy Reviews, 57*, 192-204.

Seo, H.-C., Kim, C.-H., Yoon, Y.-M., & Jung, C.-S. (2009a). *Dynamics of grid-connected photovoltaic system at fault conditions.* Paper presented at the Transmission & Distribution Conference & Exposition: Asia and Pacific, 2009.

Seo, H.-C., Kim, C.-H., Yoon, Y.-M., & Jung, C.-S. (2009b). *Dynamics of grid-connected photovoltaic system at fault conditions.* Paper presented at the 2009 Transmission & Distribution Conference & Exposition: Asia and Pacific.

Shah, R., Mithulananthan, N., Bansal, R., & Ramachandaramurthy, V. (2015). A review of key power system stability challenges for large-scale PV integration. *Renewable and Sustainable Energy Reviews, 41*, 1423-1436.

Shahnia, F., Ghosh, A., Ledwich, G., & Zare, F. (2011). *Voltage correction in low voltage distribution networks with rooftop PVs using custom power devices.* Paper presented at the IECON 2011-37th Annual Conference on IEEE Industrial Electronics Society.

Shahnia, F., Majumder, R., Ghosh, A., Ledwich, G., & Zare, F. (2011). Voltage imbalance analysis in residential low voltage distribution networks with rooftop PVs. *Electric Power Systems Research, 81*(9), 1805-1814.

Silvestre, S., Chouder, A., & Karatepe, E. (2013). Automatic fault detection in grid connected PV systems. *Solar Energy, 94*, 119-127.

Singh, B., Chandra, A., & Al-Haddad, K. (2014). *Power quality: problems and mitigation techniques*: John Wiley & Sons.

Smith, J. C., Hensley, G., & Ray, L. (1995). IEEE Recommended Practice for Monitoring Electric Power Quality. *IEEE Std*, 1159-1995.

Subudhi, B., & Pradhan, R. (2013). A comparative study on maximum power point tracking techniques for photovoltaic power systems. *IEEE Transactions on Sustainable Energy, 4*(1), 89-98.

Suruhanjaya Tenaga. (2016). Guidelines on Large-Scale Solar Photovoltaic Plant for Connection to Electricity Network (pp. 1-672). energy commision malaysia

Tan, C. N. (2014). Solar-Powered Digital Water Meter With Wireless Capability.

Tenaga, K., & dan Air, T. H. (2011). Handbook on the Malaysian Feed-in-Tariff for the Promotion of Renewable Energy. *Ministry of Energy, Green Technology and Water, Malaysia*.

Tenaga Nasional Berhad. (2005). Technical Guidebook for the Connection of Generation to the Distribution Network. *Tenaga Nasional Berhad*.

Teodorescu, R., Blaabjerg, F., Liserre, M., & Loh, P. C. (2006). Proportional-resonant controllers and filters for grid-connected voltage-source converters. *IEE Proceedings-Electric Power Applications, 153*(5), 750-762.

Teodorescu, R., & Liserre, M. (2011). *Grid converters for photovoltaic and wind power systems* (Vol. 29): John Wiley & Sons.

Theologitis, I.-T. (2011). Comparison of existing PV models and possible integration under EU grid specifications.

Timbus, A., Liserre, M., Teodorescu, R., Rodriguez, P., & Blaabjerg, F. (2009). Evaluation of current controllers for distributed power generation systems. *IEEE Transactions on power electronics, 24*(3), 654-664.

Tohidi, S., & Behnam, M.-i. (2016). A comprehensive review of low voltage ride through of doubly fed induction wind generators. *Renewable and Sustainable Energy Reviews, 57*, 412-419.

TOPSUN solar modules. (2017). 400Wp Topsun S400 PV module Retrieved 22/Jan, 2017, from http://topsun.kr/english/product/images/New%20Brochure.pdf

Troester, E. (2009). *New German grid codes for connecting PV systems to the medium voltage power grid.* Paper presented at the 2nd International workshop on concentrating photovoltaic power plants: optical design, production, grid connection.

Ünlu, M., Camur, S., Beser, E., & Arifoglu, B. (2015). A Current-Forced Line-Commutated Inverter for Single-Phase Grid-Connected Photovoltaic Generation Systems. *Advances in Electrical and Computer Engineering, 15*(2), 85-92.

VanderMeulen, A., & Maurin, J. (2010). Current source inverter vs. Voltage source inverter topology. *Technical Data TD02004004E, Eaton*.

Viet, N. H., & Yokoyama, A. (2010). *Impact of fault ride-through characteristics of high-penetration photovoltaic generation on transient stability.* Paper presented at the Power System Technology (POWERCON), 2010 International Conference on.

Villalva, M. G., Gazoli, J. R., & Ruppert Filho, E. (2009a). *Analysis and simulationof the P&O MPPT algorithm using alinearized PV array model.* Paper presented at the Power Electronics Conference, 2009. COBEP'09. Brazilian.

Villalva, M. G., Gazoli, J. R., & Ruppert Filho, E. (2009b). Comprehensive approach to modeling and simulation of photovoltaic arrays. *IEEE Transactions on power electronics, 24*(5), 1198-1208.

Vu, T. T., Tuyen, N. D., & Bang, N. L. H. (2016). Control Method for Reducing a THD of Grid Current at Three-Phase Grid-Connected Inverters Under Distorted and Unbalanced Grid Voltages. *PROCEEDING of Publishing House for Science and Technology, 1*(1).

Wang, G., Zhao, K., Shi, J., Chen, W., Zhang, H., Yang, X., & Zhao, Y. (2017). An iterative approach for modeling photovoltaic modules without implicit equations. *Applied Energy, 202*, 189-198.

Worku, M. Y., & Abido, M. A. (2015). *Grid-connected PV array with supercapacitor energy storage system for fault ride through.* Paper presented at the Industrial Technology (ICIT), 2015 IEEE International Conference on.

Woyte, A., & Goy, S. (2017). Large grid-connected photovoltaic power plants: Best practices for the design and operation of large photovoltaic power plants *The Performance of Photovoltaic (PV) System* (pp. 321-337): Elsevier.

Wu, H., & Tao, X. (2009). *Three phase photovoltaic grid-connected generation technology with MPPT function and voltage control.* Paper presented at the 2009 International Conference on Power Electronics and Drive Systems (PEDS), Taipei, Taiwan.

Wu, Y.-K., Lin, J.-H., & Lin, H.-J. (2017). Standards and guidelines for grid-connected photovoltaic generation systems: A review and comparison. *IEEE Transactions on Industry Applications*.

Yang, B., Li, W., Zhao, Y., & He, X. (2010). Design and analysis of a grid-connected photovoltaic power system. *IEEE Transactions on power electronics, 25*(4), 992-1000.

Yang, L., Liu, W., Peng, G., Chen, Y.-G., & Xu, Z. (2016). Coordinated-Control Strategy of Photovoltaic Converters and Static Synchronous Compensators for Power System Fault Ride-Through. *Electric Power Components and Systems, 44*(15), 1683-1692.

Yang, Y., & Blaabjerg, F. (2013). Low-voltage ride-through capability of a single-stage single-phase photovoltaic system connected to the low-voltage grid. *International Journal of Photoenergy, 2013*.

Yang, Y., Blaabjerg, F., & Zou, Z. (2013). Benchmarking of grid fault modes in single-phase grid-connected photovoltaic systems. *IEEE Transactions on Industry Applications, 49*(5), 2167-2176.

Yang, Y., Enjeti, P., Blaabjerg, F., & Wang, H. (2013). *Suggested grid code modifications to ensure wide-scale adoption of photovoltaic energy in distributed power generation systems.* Paper presented at the Industry Applications Society Annual Meeting, 2013 IEEE.

Yang, Y., Zhou, K., & Blaabjerg, F. (2013). *Harmonics suppression for single-phase grid-connected PV systems in different operation modes.* Paper presented at the

Applied Power Electronics Conference and Exposition (APEC), 2013 Twenty-Eighth Annual IEEE.

Yibre, M., & Abido, M. (2013). *Supercapacitors for wind power application.* Paper presented at the Renewable Energy Research and Applications (ICRERA), 2013 IZhang, Y., Ma, L., & Zheng, T. Q. (2011). *Application of feedback linearization strategy in voltage fault ride-through for photovoltaic inverters.* Paper presented at the IECON 2011-37th Annual Conference on IEEE Industrial Electronics Society.

Zhu, Y., Yao, J., & Wu, D. (2011). *Comparative study of two stages and single stage topologies for grid-tie photovoltaic generation by PSCAD/EMTDC.* Paper presented at the Advanced Power System Automation and Protection (APAP), 2011.